

New Cost Models Are Needed for Fiber Laser Based Missions

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Engineered for life



Fiber Amplifiers and Lasers are an Enabling Technology for next Generation of NASA Missions

- NASA's Science and Exploration objectives – as well as partners in NOAA, Homeland, etc - require affordable solutions to active remote sensing.
 - > Ex; NRC Decadal Survey, ESTO, ESTEC/ESA
- For a wide variety of objectives, lidars constructed using fiber amplifiers and lasers meet the mission requirements.
 - > Ex; Coyle, Application of Fiber Amplifiers for Space, ESTEC/ESA
- Mass produced fiber amplifiers and lasers, properly procured with up-screening, meet the mission reliability requirements - at considerable cost savings compared to one-off solutions.
 - > Ex; DoD Special Technology Area Review, 2001
- What is missing is an accepted cost model which differentiates between Fiber lasers and Diode Pumped Solid State lasers.

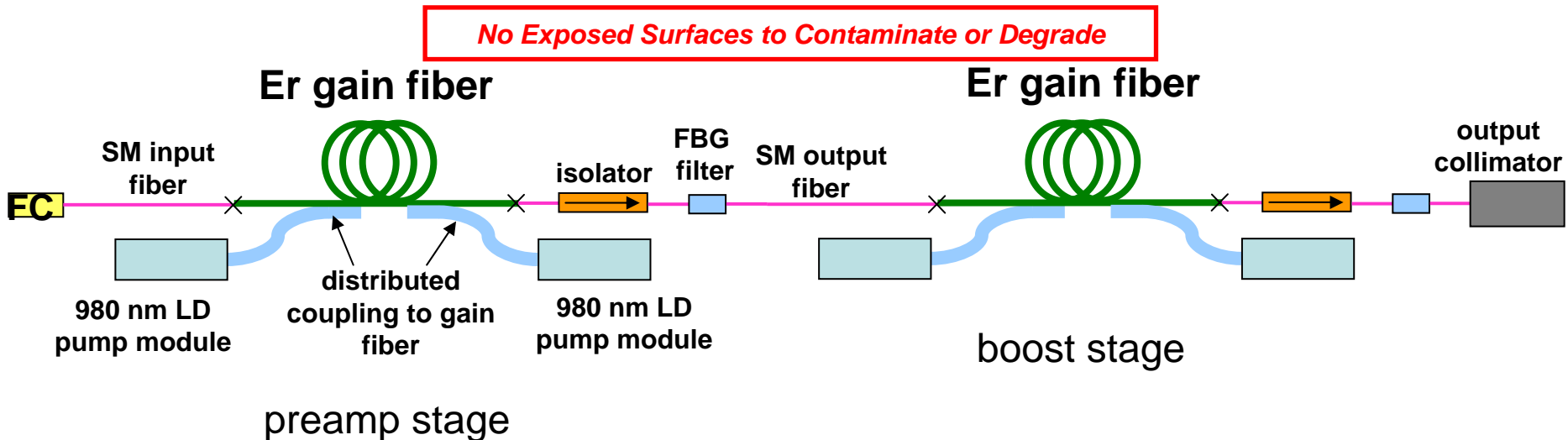
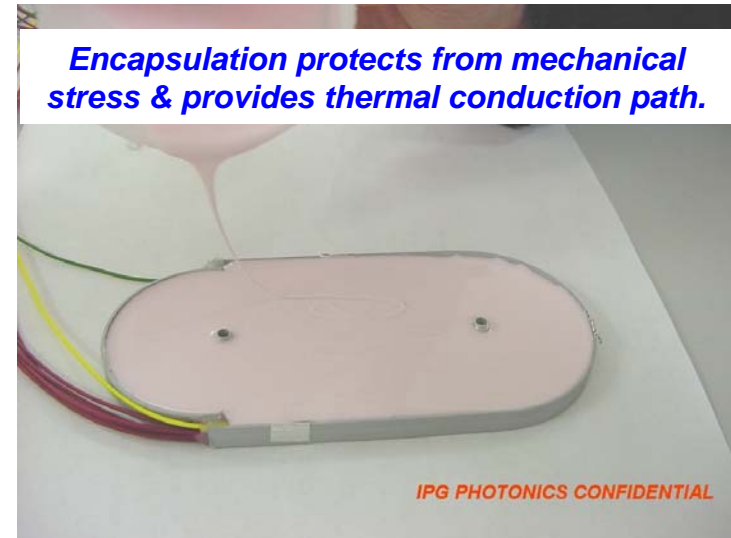
Fiber Amplifiers-Lasers Offer Significant Advantages in Terms of Managing Program Risk, Cost, and Schedule.

- **Mass produced units offer many significant advantages:**
 - **Established Manufacturing Processes**
 - > Manufacturing and Testing Processes are de-bugged.
 - > Telecordia defines test procedures and pass/fail criteria.
 - > A 'space' unit build can and should occur using the same processes and production line as the COTS products.
 - » **Lot test data will be reviewed.**
 - » **Selected component up-screening may be deemed necessary; but that does not impact process.**
 - **Established Reliability**
 - > Large manufacturing volume provides more accurate estimate of MTBF
 - **Healthy Industrial Base**
 - > Multiple US and International suppliers
 - **Significant External Sources of Research and Development Funding**
 - > Multiple agencies funding fiber technologies
 - > Reduces cost to Science Community

Components are robust, reliable and mass produced.

Fiber Amplifiers are robust, reliable and mass produced.

- Two (2) gain stages
 - optical series
- Gain Stage
 - Fiber bragg grating
 - Yt/Eb doped gain fiber
 - Distributed optical pump
 - Pump String
 - Optical isolator
- Pump String
 - Many diodes
 - Optical parallel/electrical series



Fiber Amplifiers & Lasers have Lower Complexity and Risk compared to traditional DPSS lasers.

Fiber Amplifier

No cavity

No surfaces

100X lower power density

No pump diode stress @ CW mode

Classic Pulsed Laser

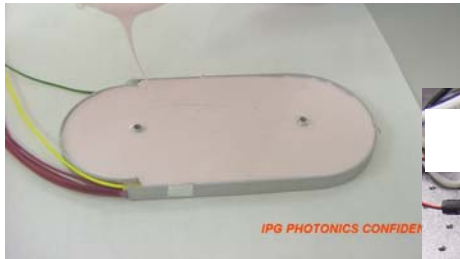
Sensitive cavity in hostile environment

100's of sensitive surfaces

High fluences destroy optics

High diode thermal cycle @ pulse mode

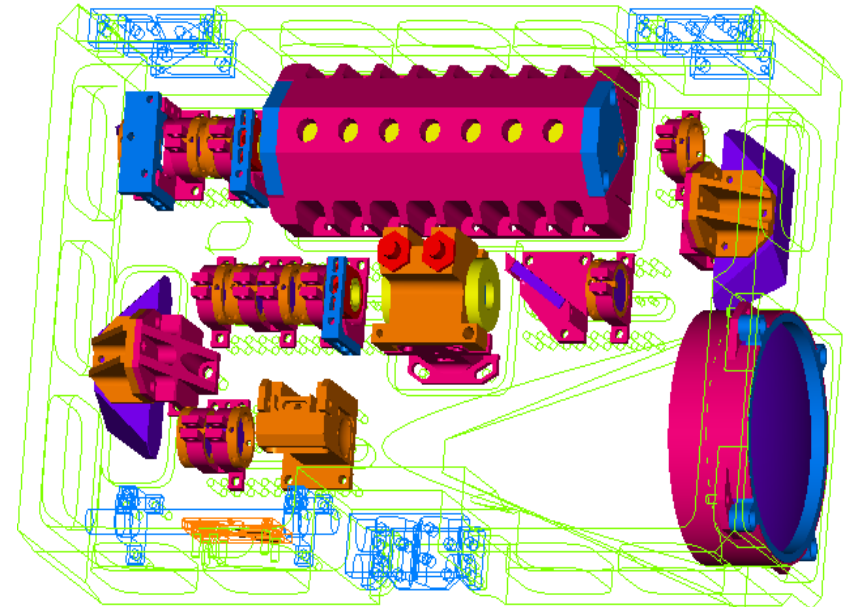
Encapsulated Gain Block



Fiber Coupled Pump Diode



Compact, Rugged.



Old photos for example only.

COTS Fiber Amplifiers are Readily Qualified.

- In 2001, ITT ran a complete LIDAR transmitter system, including off-the-shelf DFB and Fiber Amplifiers through a limited qualification test program:
 - Vibration
 - > Tested to Acceptance Level 10gRMS
 - » 3db below Qualification Level 0.15 g²/Hz (10Grms)
 - Thermal Cycle
 - > Tested to 12 cycles, +20°C to +60°C
 - » ±20 around 40C design point
 - Radiation
 - > The objective of the test was to determine the ability of the photonic components to withstand 2 years in a LEO orbit.
 - » The commercial electronics were shielded.
- **The integrated transmitter system exhibited no change in power or spectral characteristics as a result of the qualification test program.**
- ITT is preparing to thermal-vacuum test a Fiber Amplifier which leverages the lessons learned from MLCD.
 - Hermetic (true) Pump Diodes.

Comparison of Reliability Issues and Impact on Cost

Reliability Issues for Lasers for Space Flight Environment	Relative Weight	MOLA NEAR VCL Calipso	EDFA pulsed	EDFA cw	Impact on Manufacturability, Robustness, and Cost and Schedule (MRCS)
Surface Contamination ⁽¹⁾	High	Yes			Requires extremely high levels of cleanliness throughout lifetime of laser; construction, integration and test, launch, on-orbit. Sealed enclosures to reduce risk
Damage from High Fluences ⁽¹⁾	High	Yes	Yes		Contamination or poor quality coatings will result in degradation; which is a self accelerating process.
Laser Development Required ⁽¹⁾	High	Yes			Custom design significantly increases risk to MRCS
Laser LifeTime ⁽¹⁾	High	Yes	Yes		Pulsed Pump Diode Bars, Q-Switches have poor lifetime.
Pump Diode Availability ⁽¹⁾	Medium	Yes	No	No	Telecom pumps produced in volumes >500,000 year, multiple vendors, long term expanding market.
Complicated Optical Path ⁽¹⁾⁽²⁾	High	Yes			Large number of components, with complex alignment requirements increases risk to MRCS.
Modularity	Medium	Sort Of	Sort Of	Simple	Coupling/Ganging DPSS requires optical bench.
Scalability	Medium	No	Not Yet	Yes	Fiber Lidar can be scaled to higher power using multiple low power modules. <ul style="list-style-type: none"> Ex; IPG 10Kwatt fiber laser Scaling DPSS has posed problems at high energy levels.
Established and Vetted Manufacturing Process ⁽²⁾	High	No	Yes	Yes	Space qualified fiber laser have been made on same manufacturing line as commercial laser. Preserves the reliability gained from using a vetted process. Shorter, Predictable delivery times reduces schedule and cost. COTS for space costs ~10% of custom for space; <ul style="list-style-type: none"> Ex; 5watt vacuum ready EDFA by IPG costs <\$50K, versus 5watt EDFA by Lucent Gov Systems for \$500K, versus many \$M's for a GLAS-like laser. 10X-20X reduction in cost through manufacturing process and use of CW⁽²⁾

(1) *Earth Science Enterprise Independent Laser Assessment Report, 2000/2001*

(2) *DoD Special Technology Area review on Low Cost, Mass Producible Solid-State Lasers, Nov 2001*

New Cost Models Are Needed for Fiber Laser Based Missions

- What is missing is an accepted cost model which accounts for the significant differences in Manufacturability, Robustness, and Cost and Schedule (MRCS) between COTS Fiber Amplifiers Lasers and Diode Pumped Solid State lasers.
- Recommended Action
 - Joint effort by NASA, Industry and Aerospace Corp.
 - > NASA Electronics Parts and Packing program (NEPP)
 - » Identify qualification requirements over and above Telecordia
 - > Industry
 - » IPG Photonics & ITT Space Systems to update internal cost model based on most recent NEPP inputs using IPG established manufacturing processes and procedures. Provide validation data for cost model.
 - » Other suppliers to do same
 - > Aerospace Corp
 - » Develop and Validate common Parametric Cost Model